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Recreational Disturbance of Breeding Golden Plovers *Pluvialis apricarius*

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ABSTRACT

Detailed observations were made of golden plovers Pluvialis apricaria *being disturbed, during the breeding season, by people walking on the moors. During the pre-incubation period, the birds were sensitive to the presence of people within about 200 m, and flew more often. During incubation, golden plovers incubated for 96% of the time, but would have incubated for 98% of the time if they had not been disturbed. They flushed more readily in response to the presence of dogs than people on the moor, and took much longer to resume incubation when people were around. In the post-hatching, chick-guarding, period, adult golden plovers spent about 11% of the observation day reacting to people; they flew more often, increasing their energy expenditure by 15%. Their chicks hid in response to the alarm calls of their parents, so could neither feed nor be brooded. In some cases, parents led their broods away from what had been satisfactory nest sites into quieter areas of moor, and encountered considerable resistance from the neighbours whose territories they invaded.*

INTRODUCTION

There is some evidence that the population of golden plovers *Pluvialis apricaria* breeding on the southern moors in the Peak District National Park, England, has declined over the last 15 years, and a suspicion that this is the consequence of increased recreational disturbance (Yalden, 1986). We have demonstrated for one study area that recreational pressures can be

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very high—up to 8000 people visit the area during the birds' breeding season (mid-April–mid-July), and people may be present for 100% of the observation day (0930–1800 h) at peak weekends (Yalden & Yalden, 1988*a*). On open, blanket bog vegetation, people do not necessarily restrict themselves to footpaths; in two areas, we found over 30% of them wandering more generally on the moor. They are frequently accompanied by dogs (1 dog for 25 people is a typical ratio), and over 60% of the dogs seen were not on a lead. A more extensive survey of recreational pressure on the moorlands of the Peak Park has confirmed that these results are quite typical of the Park as a whole (Anderson, 1988).

Observing that recreational pressure is high does not, of course, demonstrate that it is necessarily harmful to birds; some species tolerate, and some even benefit from, human activities. For example, it has been shown that snow buntings *Plectrophenax nivalis* have increased in the Cairngorms in winter, feeding in lay-bys on picnic scraps left by tourists (Watson, 1979).

The conventional way to demonstrate that humans have a deleterious effect on birds is to look for negative correlations in their density or distribution. Thus, curlews *Numenius arquatus* breeding on duneland in The Netherlands have been shown to avoid visitor pressures of over 1000 ha^{-1} (van der Zande, 1984); oystercatcher *Haematopus ostralegus*, redshank *Tringa totanus* and Kentish plover *Charadrius alexandrinus* suffer from heavy pressure and benefit from protection (de Roos, 1981). Correlations of this sort are important evidence, but can be spurious, the consequence of independent interactions between birds, people and habitat, or between birds, people and time. Nor do such correlations explain how the changes in bird populations come about, information which would be important in devising conservation measures to ameliorate any problems.

This paper presents a detailed study of the ways in which people and golden plovers interact. We were particularly concerned to evaluate the seriousness of disturbance at different stages of the breeding cycle (pre-incubation, incubation, post-hatching) and to examine the ways in which any reduction of population might have been produced.

METHODS

The study was carried out at the Snake Summit (Nat. Grid Ref. SK 087929), where the main A57 trunk road from Manchester to Sheffield is crossed by the Pennine Way long-distance footpath (Yalden & Yalden, 1988*a*). Observations were conducted from a car parked at the roadside. Presence of people, their location and route, also the presence of dogs, was recorded and analysed either in 15-min periods (1986) or in 5-min periods (1987–88). At the same time, the presence of golden plovers and (in the post-hatching period) their chicks was recorded, together with records of their behaviour (flying, alarming, brooding, fighting). A 20–60 × zoom telescope was used to watch the birds; during particularly busy periods observations were recorded on a tape-recorder and later transcribed, otherwise they were logged directly in 5-min periods. All observations of behaviour were made by P. E. Y. and are therefore consistent in that respect.

Incubation was monitored by placing a temperature-sensitive bead, connected to a small radio transmitter (Biotrack SR-1), in each nest that was located. The transmitters each operated on a different frequency, and we were able to monitor up to four nests simultaneously. The bead was pushed up through the bottom of the nest-cup, and projected nearly to the level of the top of the eggs; it thus responded immediately when the incubating bird flushed or returned to the nest. The transmitter was buried nearby in a clump of vegetation, and the short projecting aerial evidently did not distract the birds. The signal was pulsed, the repetition rate being higher at higher temperatures. The cause of flushing still had to be monitored by observation, and most of the data-logging was also done manually; we left the receiver tuned to the most vulnerable nest, and tuned in to the others at 5-min intervals.

It is not possible physically to watch more than one nest site or brood at a time, and the study was also dependent on birds deciding to nest within reasonable visual range of the car. In common with many behavioural studies, it is therefore difficult to assume statistical independence of the data. Nevertheless, all the conclusions we draw are based on 2 or 3 years' results, and relate to at least 12 nesting attempts—details of sample sizes are given as appropriate under results.

In the post-hatching phase, golden plovers certainly react to anyone within about 200 m of their chicks (Yalden & Yalden, 1989). In the pre-laying period, they do not overtly proclaim that they are being disturbed by calling continuously (alarming) as they do when they have chicks. It seems probable that they are nevertheless sensitive to anyone within 200 m, and we have therefore compared their behaviour between when people are present within 200 m and when they are absent. The distance was estimated in relation to various landmarks (footpaths, nest sites, etc.) and in 1988 to a series of short marker posts, whose relative positions were established by pacing them out (cf. Yalden & Yalden, 1989).

Our results are thus of two sorts. We have some statistical comparisons of the behaviour of birds when people are present or not, and we have narrative evidence of the sorts of interactions between birds and people (or their dogs) which might be harmful.

RESULTS

Pre-laying period

During the pre-laying period, golden plovers spend long periods standing in their territory. One pair, watched in total for 21·25 h over 3 days in 1988, was present for 93% of the observation time. In 1986, on the Saddleworth Moors study site (Yalden & Yalden, 1988*a*), birds were present for 62% of 55·75 h of observation, spread over seven days. A little of this time is spent in mating behaviour and nest building, but mostly the birds just stand, close together, in their territory. (They do not feed on the moors at this time of year; indeed from our observations the adults barely feed on the moors at all, but fly off to pastures about 5 km away.) This attendance in their territory would certainly allow them to judge its suitability, and its vulnerability to disturbance.

The clearest example of such disturbance occurred on Sunday 27 April 1986; a male golden plover was standing in Area VI, below the Pennine Way,

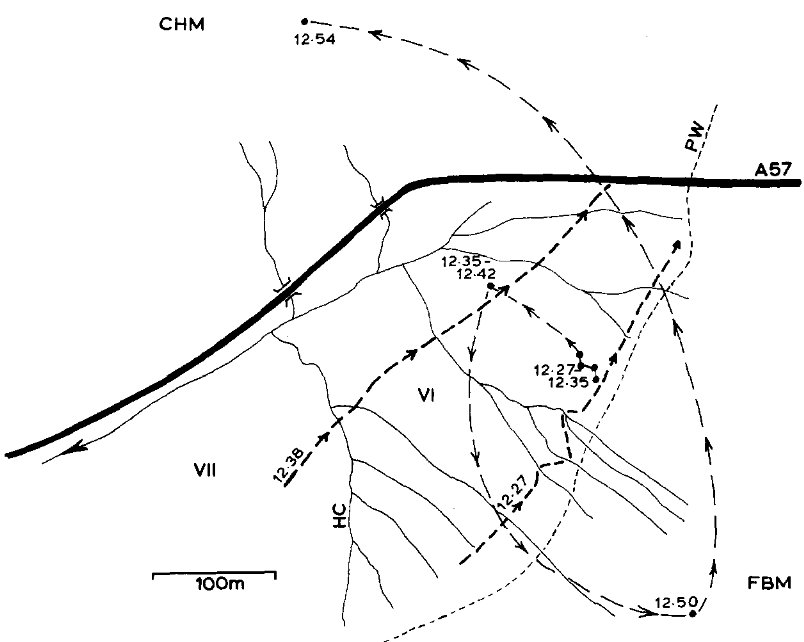

Fig. 1. Disturbance to a male golden plover at Snake Summit on Sunday 27 April 1986. Times (BST) given beside tracks of golden plover (—→) and people (- — →). CHM, Cold Harbour Moor; FBM, Featherbed Moss; HC, Holden Clough; PW, Pennine Way; VI, Area VI; VII, Area VII.

at 1226 h (Fig. 1), when a hiker walking north-west of the Pennine Way towards the Snake Summit travelled through the area, zig-zagging to avoid the peat hags. This caused the golden plover to alarm, then, at 1235 h fly a short distance (*c.* 100 m) west, further into Area VI. At his nearest, the hiker was about 50 m from the bird. At 1238 h, another hiker leaving Area VII crossed Holden Clough into Area VI, and walked out to the A57; the golden plover, in view throughout this period, was clearly alarming and keeping the hiker in view. At 1242 h, it flew back south-eastwards about 400 m onto Featherbed Moss and was temporarily lost to sight. At 1246 h, some alarming was heard from Featherbed Moss, and at 1250 h a golden plover flew up into song flight over the Moss; two more golden plovers joined it, flying their own circuits, landing at 1254 h. We interpret this as indicating that the bird displaced from Area VI had infringed the territories of its two neighbours, causing all three to proclaim their boundaries. We suspect that the displaced bird nested on Cold Harbour Moor, but as we did not colour-ring adults this cannot be proved.

TABLE 1
Number of 5-Min Observation Periods in which Golden Plovers (GP) Were Observed to Fly, in Relation to Whether or Not Hikers Were Within 200 m of the Birds

	People			*Total*
	Not within 200 m	*Within 200 m*		
		Observed	*(Expected)*	
GP fly	43	24	(7·6)	67
GP stay	405	33	(49·4)	438
Total	448	57	(57·0)	505

$\chi^2 = 41{\cdot}2$, $p \ll 0{\cdot}001$.

Records of this sort suggest a statistical test of the reality of recreational disturbance in this period; golden plovers should fly more often when people are present within 200 m. This was examined for 21 days of observation, relating to 5 territories, in 1986 and 1988 together. Golden plovers fly relatively infrequently (in 13% of the 5-min observation periods) but they certainly fly much more readily when people are present within 200 m (Table 1), and the difference is highly significant. Golden plovers do not always fly off when people are near; they will often walk quietly out of the way, especially if people pass tangentially or stay on the main road.

Incubation

Over the three years, temperature-sensitive radios were placed in 9 nests and monitored on 59 nest-days, a total of 399 h of records. We used these to ascertain constancy of incubation, to alert us to breaks in incubation, to relocate the nests ourselves (to check on proximity to hatching) and to check the return times after disturbance.

Constancy of incubation

During our observations, incubating golden plovers were sitting for 96·6% of the time, even including the accidental disturbance that we recorded (Table 2); excluding such disturbance they were sitting for over 98% of the time. Our observations were concentrated in the period 0900–1800 h, since our prime concern was with recreational disturbance, and we could have under-recorded breaks during mate change-overs. Even so, it is clear that golden plovers incubate nearly constantly, as Parr (1980) and Byrkjedal (1985) also found.

Recreational interruptions of incubation

In observations of 6 nests, we recorded 13 interruptions of incubation; these included one case where a family flying a kite over the nest disturbed it, once when a birdwatcher strayed too close and stayed in the area for over 2 h, 3 records of hikers by themselves and 8 cases where people accompanied by dogs caused the bird to leave. Analysing the observations for all occasions when people approached within 200 m of these nests, it is evident that people

TABLE 2
Constancy of Incubation by Golden Plovers

Year	*Nest*	*n (days)*	*n (5-min)*	*% Constancy of incubation*	
				Inclusive	*Exclusive*
1986	VI	11	950	96·0	96·8
1986	MEM	3	265	88·7	94·3
1987	LFB	2	166	94·6	94·6
1987	CHM	9	792	98·7	98·7
1987	I	8	704	99·3	99·7
1987	UFB	5	446	100	100
1988	UFB	11	790	96·7	99·9
1988	CHM	5	369	99·2	100
1988	RHS	5	305	89·8	98·4
Total	9 nests	59	4 787	96·6	98·4

The number of 5-min records when birds were, or were not, sitting, using only days with at least 2 h of observation. Calculated either including or excluding periods of accidental disturbance

TABLE 3
The Likelihood of Golden Plover (GP) Incubation Being Interrupted by People Accompanied by Dogs Passing within 200 m of the Nest Site (85 Observations of 6 nests, 1986–1988)

	People		*Total*
	With dog	*Without dog*	
GP put off	8	5	13
GP sat tight	4	68	72
Total	12	73	85

Fisher's Exact $p = 0.00002$.

accompanied by a dog are much more likely to cause the golden plover to interrupt incubation than people alone (Table 3).

Distance of disturbance to incubation
For both the 13 accidental disturbances mentioned above and a further 83 deliberate disturbances when we went to check the nests for hatching, we

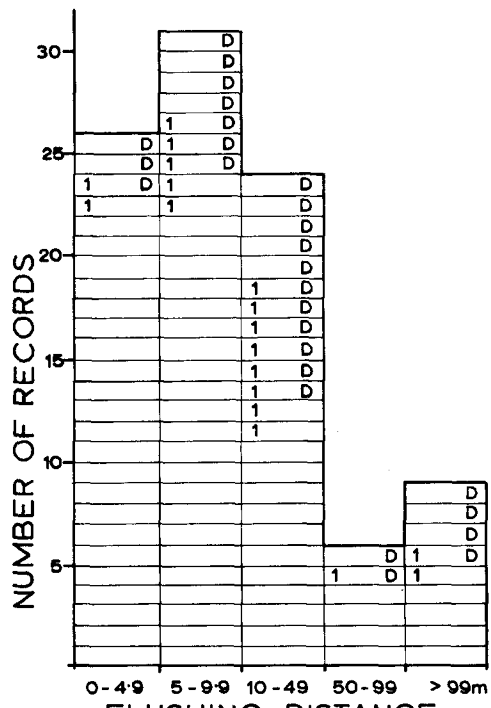

Fig. 2. Distances at which incubating golden plover flushed, grouped into irregular distance categories. Records when dogs were present (D) and first visits (1) are identified ($n = 96$ records).

TABLE 4

Distances at which Incubating Golden Plovers Flush[a] in Relation to (*a*) whether the Nest was being Visited for the First Time, (*b*) whether a Dog Accompanied the People.

	Golden plover flushed at		*Total*
	0–9·9 m	*Over 10 m*	
(*a*)			
First visit to nest	7	11	18
Subsequent visit	50	28	78
Total	57	39	96
($\chi^2 = 3{\cdot}85$, $p = 0{\cdot}047$; Fisher's Exact $p = 0{\cdot}09$)			
(*b*)			
Dog present	10	17	27
No dog present	47	22	69
Total	57	39	96
($\chi^2 = 7{\cdot}77$, $p = 0{\cdot}006$; Fisher's Exact $p = 0{\cdot}01$)			

[a] Based on 96 records.

estimated the distance at which the bird flushed. These distances ranged from 1 m to over 200 m, a variability which makes analysis difficult and perhaps statistically dubious (Fig. 2). The variation was partly due to the difference between our cautious approach to nests which we knew and the more brusque approach of ourselves or others to unknown nests (in our case, that is, when we initially discovered them). A comparison of whether the golden plover flushed at less, or greater, than 10 m distance with first or later visits might be statistically significant (Table 4), depending on whether one accepts the χ^2 or Fisher's Exact Probability. There is, however, a strong suspicion in our results of individual variability. At 3 nests, in a total of 22 visits to check the progress of incubation, the birds flushed at less than 10 m every time; yet at 2 other nests, in 9 re-visits, only once did the bird flush at about 10 m, and on other occasions flushed at ranges of 30 m to over 100 m. This suggests Ratcliffe's (1976) postulated dichotomy of 'sitters' and 'fliers'. Another, very evident, source of variation was the presence or absence of a dog accompanying the people; golden plovers are certainly more likely to flush at greater distances when a dog is present (Table 4).

These data are too few, and their statistical independence too dubious, to allow more complex, multivariate, analyses. They also suffer from bias: it is easy to see, and record fairly precisely the distance, when a bird flushes close to the observer, whereas a distant bird may slip away unobserved. However, the few cases when the birds flushed at greater ranges, and also in response to dogs, are perhaps much more significant than the many cases when the birds tolerated close approaches by ourselves, sometimes with our labrador.

Return times

Using the temperature-sensitive radios, we were able to time the return of the incubating bird on 56 occasions, relating to 9 nests over 3 years; these followed both accidental (recreational) disturbance and our own visits to the nests. The quickest return was 5 min after we had left a nest, while the longest timed return was 129 min, though two longer absences, of at least 149 and over 300 min were also recorded. Return times were longer when other people were present on the moor during the putative return period; the median return time in 39 cases when no-one was on the moor was 17 min (range 5–83 min), compared with a median of 80 min (range 13–over 300 min) in 17 cases when people were present. The difference is highly significant (Meddis non-specific test, $H = 23{\cdot}1$, $p = 0{\cdot}00003$).

Post-hatching period

Some observations were made of 6 broods of golden plovers, covering 50 days of observation and 2473 5-min observation periods. However, most records relate to 3 broods, one each year, which provided 12, 17 and 16 days of observation. The other broods moved out of range of the observer after 1–3 days of observation.

Adult attendance

Adults were visible, guarding their chicks, for about 78% of the observation periods; in fact, on most days their attendance was around 95%, falling off for the two UFB broods only when the chicks were over 32 days old (Table 5). This high attendance is important for this study, since reactions to people or other disturbance can only be recorded when the birds are visible.

Reaction to people

Each 5-min observation period was scored, hierarchically, for presence of golden plovers, whether they flew, and whether they alarmed or showed other anxious behaviour. These periods were also scored for whether people were within 200 m of the golden plovers, and the anxiety behaviour was attributed to the presence of people, to other birds (including reacting to other golden plovers, attacking pageing dunlin *Calidris alpina* (Yalden & Yalden, 1988*b*) and responding to raptors) or assumed to be spontaneous (Table 5).

Overall, people were present for nearly 15% of the observation periods, and the golden plovers reacted to them for over 11% of the time. This

TABLE 5

Observations of Adult Golden Plovers (GP) Guarding their Chicks in the Post-hatching Period. All scores are of numbers of 5-min observation periods: when Golden Plovers were visible; when they were visible and people were present within 200 m; and when they were disturbed, either anxious or flying, in response to people, other birds, or spontaneously.

Brood	*Year*	*Age of chicks (days)*	*Observation periods*	*GP visible*	*GP visible + people present within 200 m*	*GP disturbed by*					
						People		*Other birds*		*Spontaneously*	
						Anxious	*Flying*	*Anxious*	*Flying*	*Anxious*	*Flying*
VI	1986	2–21	892	535	134	58	45	8	1	28	30
UFB	1987	3–37	1 028	910	98	39	38	15	27	10	62
I	1987	3	92	68	11	1	10	0	3	0	14
UFB	1988	5–34	899	813	43	30	8	24	15	75	36
I	1988	1–3	186	93	53	17	15	0	0	3	1
RHS	1988	9	79	54	23	5	16	1	0	2	5
	Total		3 176	2 473	362	150	132	48	46	118	148
	% (of 2 473)			77·8	(14·6)	(6·1)	(5·3)	(1·9)	(1·9)	(4·8)	(6·0)

	People		*Total*
	Within 200 m	*Not within 200 m*	
GP flying	132	194	326
GP not flying	230	1 917	2 147
Total	362	2 111	2 473

($\chi^2 = 204{\cdot}4$, $p \ll 0{\cdot}000\,01$)

reaction time was in addition to nearly 4% of their time reacting to other birds and 11% of spontaneous activity. The clearest category of disturbance is the flying (since some anxiety behaviour might come from trying to maintain contact with the chicks or with a mate), and the golden plovers flew about 5 times more frequently when people were present. Putting the same results another way, golden plovers were observed to fly in 194 periods when no-one was present and a further 132 periods when people were present, so that human disturbance increased the amount of flying by 68%; flying is, of course, an energetically expensive activity, probably about ten times as expensive as standing on guard (Barnard & Thompson, 1985). Similarly, other anxious behaviour was increased through the presence of people by 90%.

The extent to which golden plovers spent their day reacting to people varied, of course, with the day of the week and with the particular location of the brood in relation to footpaths; public use of the moors is much higher at weekends and bank holidays, and much higher on or near main footpaths (Yalden & Yalden, 1988*a*), reaching 100% of the observation day at peak times on the main paths. In order to investigate this point further, in particular to seek either a degree of habituation by the birds or a ceiling level above which they would not tolerate disturbance, we plotted the relationship between the amount of time birds spent in anxiety behaviour (including alarming and flying) and the amount of time people were present in their territories. The result (Fig. 3) is not clear-cut, but does present

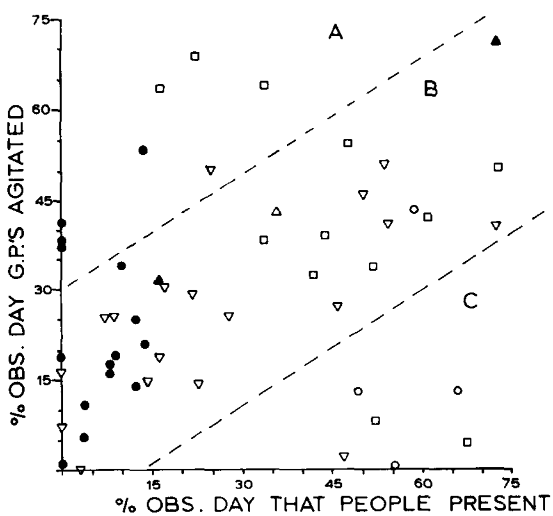

Fig. 3. The proportion of each observation day (5-min recording periods) in which golden plovers displayed anxiety behaviour (alarming, running, flying) compared with the proportion of that day when people were present in the territory. The clusters A, B and C are discussed in the text. □, VI 86; ▲, I 87; ▽, UFB 87; ○, I 88; △, RHS 88; ●, UFB 88.

the results in a visually useful way. There is a methodological problem, however, because if we had selected only to plot periods when birds were present and reacting to people, we would have obtained the relationship we expected, but been vulnerable to the accusation of bias by selecting our results (i.e. by omitting periods when the birds failed to react to people present). Each point on Fig. 3 therefore represents a day of observation, with all anxiety behaviour (to birds, and spontaneous, as well as to people) plotted against all visitor presence (whether or not the birds were seen). There appear subjectively to be three clusters of results. Cluster A (Fig. 3) contains 8 days when the golden plovers were very anxious, though few or no people disturbed them; these include 3 days when the golden plovers spent some time attacking dunlin or other golden plovers, and 3 days when a lot of calling was registered (2–4 days post-hatching) from a brood very near to the car/hide, which was probably in fact contact-calling to the chicks (cf. Byrkjedal, 1985). The central cluster of results (Fig. 3B) suggests a linear relationship of anxiety to the presence of people, superimposed on a level of perhaps 15–20% 'spontaneous' anxiety behaviour. There might be a ceiling level, about 55% of the day reacting to people, but this result is not convincing. However, cluster C contains 8 days when people were present in the territories for 30–70% of the day, yet golden plovers hardly reacted to them. In every case this is because the adult golden plovers had in fact left their territories, either flying off the moor or having led their chicks away onto a quieter area of moorland.

Chicks hiding

It is presumed that, by alarming, the adults warn their chicks of the danger, allowing the chicks to hide (but stopping them from feeding). In that case, chicks are much more likely to be seen by the observer in an observation period when the moor is quiet than when people are present. This expectation is clearly realised, and the difference is highly significant (Table 6).

Brooding and feeding

Chicks were difficult to see, and only visible for about 27% of the time (Table 6); opportunities for recording brooding and feeding were therefore few. In 1986, the weather was mostly fine when the brood was being reared, and brooding was only seen on one day; on 24 June, at 3-days old, the brood was watched feeding, then brooding for 9 min, feeding again and then brooding for 10 min until interrupted by approaching walkers who were about 200 m away. In 1987, the weather was generally poorer, and 35 brooding periods were timed, as well as 33 chick-feeding periods. The most significant observations, for this study, concern Tuesday 2 June, when both adult golden plovers

TABLE 6
Visibility of Golden Plover Chicks in Relation to the Presence of People
($n = 1844$ 5-min observation period)

	People		*Total*
	Present within 200 m	*Not present*	
Chicks visible	18	480	498
Chicks not visible	127	1 219	1 346
Total	145	1 699	1 844

$\chi^2 = 17{\cdot}0$, $p = 0{\cdot}000\,16$

were in attendance on a 3-day old brood of 3 chicks beside the Pennine Way North (Fig. 4). Observations of the brood lasted from 1043 to 1740 h BST, during most of which it was raining. It was possible to time 11 brooding periods (3–17 min; $\bar{x}$ 11·9, SD 4·04) as well as 7 feeding periods ($\bar{x}$ 5·4 min) but three of the brooding periods were terminated by recreational disturbance, twice by hikers and once by a runner. On each occasion, it took the adult 3–4 min to resume brooding, and two interruptions occurred during heavy rain. If the pattern of 10–12 min brooding periods interspersed with 4–10 min feeding bouts represents the optimum pattern for such young chicks, additional interludes of 3–4 min when neither feeding nor brooding is possible represent major disruptions of behaviour.

Overall, brooding periods were relatively consistent in length, at around 10 min (Table 7) with some indication that older chicks might be brooded for much longer; this is less surprising than the observation that chicks as old as 28 days were indeed brooded. By this age, they have virtually full plumage and are nearly full size (linearly, though still much lighter than adults). Feeding periods were much more variable, and much longer in older chicks. Young (3-day-old) chicks feed in 10 min periods, but older chicks may feed for 40 min or more between brooding periods; indeed, this figure is probably not very meaningful, because in good weather older chicks, in particular, will not be brooded at all and may well feed intermittently throughout the day.

Moving off

The episode detailed in the previous section concerned a weekday, i.e. a relatively quiet time. Overall, the parents were disturbed by people for 11% of that day (49 min out of 7 h 27 min), but at peak weekends, that area may be disturbed for 100% of the observation day (Yalden & Yalden, 1988*a*). The obvious response might be for the adults to lead their chicks away from the

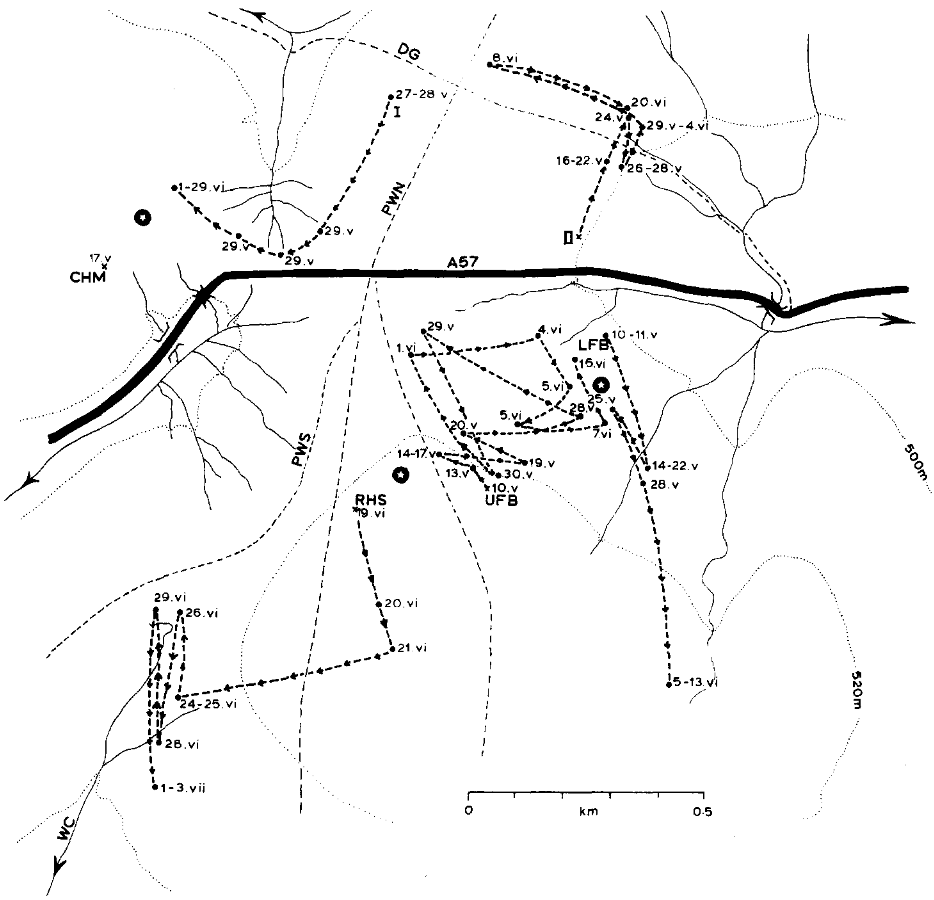

Fig. 4. Areas used by 5 broods of golden plover chicks under observation in 1988 (cf. Tables 5 and 7), and tracks (with dates) of 4 broods which moved away from their nest site apparently in response to excessive human disturbance. ×, known nest sites; ✪, sites where fighting recorded. The UFB birds did not move far from their natal area, but did take over the natal area of LFB birds, and constrained both the LFB and RHS broods.

disturbed zone, which is precisely what happened with this particular brood; on Friday 5 June, only three days later, the male was seen, with at least one chick, about 100 m further southwest, away from Pennine Way North toward the very quiet zone of Cold Harbour Moor, and during the day it moved further onto Cold Harbour Moor (Fig. 4). It showed some aggression to the resident dunlin between 1238 and 1420 h, but at 1526 h was close to another male golden plover. From 1542 to 1554 h and again from 1622 to 1628 h, there was fierce fighting between the two males, something we have not observed at all on the moors during the period when territories are being established in late March–early April. The resident Cold Harbour Moor golden plovers had much older chicks, about 3 weeks old (one at least of

TABLE 7
Duration (in Minutes) of Completed Bouts of Brooding and Feeding Periods of Golden Plover Chicks, Snake Summit, 1986–1988[a]

Brood	Year	Age (days post-hatch)	Brooding			Feeding		
			n	$\bar{x}$	SD	n	$\bar{x}$	SD
VI	1986	3	1	9	—	2	7	0
UFB	1987	3	11	9·1	2·7	9	8·9	3·3
UFB	1987	4–8	7	8·1	2·9	8	48·9	55·9
UFB	1987	25–28	7	17·9	11·3	7	48·6	37·0
I	1987	3	10	11·9	4·0	7	5·4	2·3
UFB	1988	9–20	7	11·1	3·1	3	8·7	2·3
Overall			43			36		

[a] Observations of 4 broods, made on 14 days.

which was present during this afternoon). Fighting was seen again, in the same area, the next afternoon, and with lessening intensity at least over the next 12 days. Exactly the same thing happened in 1988; we failed to find the nest in Area I that year but, from the behaviour of the adults, it hatched on 26 May. On Sunday 29 May, the parents were moving their brood away from the Pennine Way toward Cold Harbour Moor; on the following Wednesday and Thursday (1–2 June), fighting, flying, stalking and 'yodelling' (the aggressive 'too-roo—too roo'; call V, Cramp & Simmons, 1983) occupied up to 91% of the observation day, and some aggression was recorded through the following 14 days. A further three broods in 1988 moved away from where they hatched to quieter parts of the moor. A nest in Area II, which hatched on 16 May, was not found until 2 weeks later; it had been within 50 m of the main A57 road. When first seen, the brood was about 200 m away from the road, near Doctor's Gate Path, and stayed thereabouts for their first week, but subsequently moved even further north, beyond that path and out of our view. A nest on lower Featherbed Moss, about 100 m south of the A57, hatched on about 10 May; by Saturday 14 May this brood had moved about 400 m south, stayed there to 28 May, and then moved a further 400 m south by 5 June. Another rather late nest, monitored through incubation, hatched on 18 June; by 20 June these had moved 200 m south-east up Featherbed Moss, away from the paths, and by Friday 24 June they had moved 600 m south-west into the gullies around the head of Withins Clough. Possibly other neighbours constrained them to edge 100 m back toward the Pennine Way on Sunday 26 June, where they were disturbed for 40% of the time they were in view, and on Tuesday 28 June they had moved back 300 m to the south.

Direct mortality

Very young chicks are exceedingly vulnerable, and we killed perhaps 3 (out of 52 handled) in accidents (two trodden on, one was apparently mis-brooded, dead beside the nest cup in a crouched position). Older chicks are more robust, and it is therefore disturbing to record three which had apparently been killed by dogs. One chick, about 3 weeks old and weighing 105·5 g, was found freshly dead beside a footpath on 17 June 1987; at post-mortem it had an obvious canine tooth wound on its right wing, near the elbow joint, and another, in the middle/right flank associated internally with substantial haemorrhaging over the right femur and adjacent flank. The punctures were about 30 mm apart, consistent with the canines of a dog. The chick had been in good condition, with noticeable fat reserves over the pectoral muscles. A second bird, a juvenile about 5 weeks old, was found on 8 July 1987, but had been dead a few days and was less easy to post-mortem. There appeared to be puncture marks in the skin either side of the thorax, and depressions about 25 mm apart in the pectoral muscles. There appeared to be clotted blood around the heart just inside one of these punctures. The third case, a young chick, was ringed at the nest on 11 May 1988, and last seen alive on the evening of 22 May at 1915 h. On 5 June, its decayed corpse was found in the area where it had been watched, only 70 m off the Pennine Way. It was little more than a skeleton, and cause of death could not be established; it had not, however, died of starvation, for its crop contained at least 45 adult *Tipula subnodicornis*, 1 lycosid and 1 liniphyid spider and 1 curculionid beetle. A predator would have carried off or eaten these corpses, and we therefore conclude that these three deaths were due to dogs; their proximity to footpaths suggests the same.

DISCUSSION

When we began this study, we suspected that golden plovers, and other ground-nesting moorland birds, would be most vulnerable to disturbance during incubation; we envisaged either that the eggs would chill and die if the birds were flushed too frequently, or that they would be rendered vulnerable to predation by crows and gulls. Our results suggest that incubation is probably in fact the least sensitive period. Sitting birds would often tolerate us approaching to within 10 m of the nest, and several successful nests were located in 'quiet corners' of the moor, well within 200 m of paths and the road, a proximity that they no longer tolerated when they had chicks. We also found relatively little evidence of nest predation (Yalden & Yalden, in prep.). This is not to imply that they are invulnerable during incubation. Their greater sensitivity to dogs than to people must cause concern, when we estimated that the area is used during the breeding season by about 300 dogs, with over 60% of them off the lead (Yalden & Yalden, 1988*a*). The reluctance of a flushed golden plover to return to its nest when people were present on the moor is also cause for concern when, at peak times, this can be throughout the day from 0930 to 1830 h (Yalden & Yalden, 1988*a*, Fig. 3). The poor hatching success in this area in 1988 (when half the eggs in active nests failed to hatch, Yalden & Yalden, in prep.) may have been due to such interrupted incubation, especially since, as both we and Byrkjedal (1985) found, incubation constancy is normally about 98%.

Adult golden plovers are most obviously disturbed by people during the post-hatching period, when they are guarding their chicks. They call anxiously ('alarm') at anyone within about 200 m (Yalden & Yalden, 1989), and may fly or run anxiously round them throughout the period of their presence. Both the alarming itself and the anxious behaviour must be energetically demanding; they call about 40 times min^{-1} when alarming (time for ten calls, $\bar{x} = 16$ s, SD 4·1, $n = 12$) and regularly keep up this rate of calling for the 15–20 min that it takes a hiker to cross the territory. Using the energy costings suggested by Barnard & Thompson (1985) and taking alarming to be equivalent to ground chasing ($5 \times$ BMR), we can suggest that recreational disturbance might make chick guarding 15% more expensive for each adult golden plover (Table 8). The extra 7 kcal required daily by this estimate imply, at a food intake rate of 2 cal s^{-1}, an extra 58 min of foraging, time which is spent away from the moors on pastureland, and therefore implies less efficient guarding of the chicks. These putative extra costs to the adults are likely to be much less serious than the costs to the young chicks, but we cannot evaluate the latter. It is clear that chicks do hide in response to their parents' alarm calls, and can therefore neither feed nor be brooded. At present we have insufficient knowledge of their metabolic rates, feeding rates or overall activity patterns to evaluate the costs of these interruptions; in our own studies, it was difficult enough to see the chicks, and we certainly could not count peck rates. In any case, such costs may be unimportant in warm weather, when metabolic costs are low and insects are abundant, yet fatal in cool, damp conditions. In our crude comparison of fledging success between this heavily disturbed moorland and the quieter area 15 km away (Yalden & Yalden, in prep.) we found no apparent difference between the two study areas; however, we scored as 'successful' any territories that were occupied by alarming parents for five weeks or more. If, on average, territories on the quiet area fledged 2 chicks per brood, as against 1 chick per brood in the disturbed area, we could not have recorded the difference.

Perhaps the most significant results are the sensitivity of the pre-incubation golden plovers, and the post-hatching birds moving with their chicks away from their nesting areas, apparently in relation to disturbance.

TABLE 8
Estimated Daily Energy Costs to Adult Golden Plovers of Recreational Disturbance

Period	*Activity*	*Time (h)*	*BMR multiple*	*Energy costs (kcal)*		
				Per 24 h	*No people*	*People present*
Night	Rest	7·00	1	25·77	7·52	7·52
Observation day (9 h)	Anxious	0·60/1·15	5	128·85	3·02	5·76
	Flying	0·70/1·19	12	309·24	8·42	14·26
	Guarding	7·69/6·67	1·25	32·21	9·61	8·33
Rest of day (8 h)	Anxious	0·54	5	128·85	2·68	2·68
	Flying	0·62	12	309·24	7·49	7·49
	Guarding	6·83	1·25	32·21	8·54	8·54
	Total	23·98	—	—	47·28	54·58

Approximate costs of various activities (in multiples of BMR) are taken from Barnard & Thompson (1985). In calculating these budgets, it is assumed (1) that a 7-h May night is spent resting/brooding at BMR; (2) that the proportion of time spent during the 9-h observation day conforms to the pattern of Table 5; (3) that the rest of daylight is spent in the same proportions as the observation day without people. Energy expenditure is overestimated by assuming that, for example, flying occupies the whole of a 5-min period; this is balanced by using the modest estimate of 12 × BMR, rather than, say, 15 × BMR.

With hindsight, this is the obvious response of a bird to too much disturbance; because it is not a dramatic interaction (as, for instance, is alarming), its importance has perhaps been underestimated. Movements in the pre-incubation period are likely to result in the birds moving off the study area completely; this is presumably the cause of the low populations recorded in this study area by Yalden (1986), and in the first year of this study. If there are nearby moors which can absorb these displaced birds, the population as a whole will not decline; and in recreationally quieter years, such as 1980, such displaced birds or their offspring might repopulate the study area, as seems to have happened also in 1987 and 1988 (Yalden & Yalden, in prep.). Moving around with chicks in the post-hatching period must be constrained by the proximity of neighbours. The fierce fighting which we observed in both 1987 and 1988 as the Area I birds moved onto Cold Harbour Moor must have been as energetically expensive as reacting to people, and equally inefficient as guarding. In 1986, with only 2·5 pairs km^{-2} and a high (45%) breeding failure, surviving broods had plenty of space into which to move in avoiding people. Even in 1988, with 5·6 pairs km^{-2} in the study area as a whole, the 2 km^2 under surveillance at Snake Summit contained only 5 pairs, not the 11 pairs that might have been expected. Because it is at the 'crossroads' between the Pennine Way and A57, a major access point to the moorlands, and has several subsidiary paths as well (Doctor's Gate, 'Stake Path', 'Ash Path'—Yalden & Yalden, 1988*a*), this area is likely to be the first to show a reduced population as a result of disturbance.

Thus, we conclude that golden plovers are vulnerable to disturbance at all stages of the breeding cycle, but the principal mechanism producing a low breeding population is avoidance behaviour during the period when they are selecting their territories at the start of the breeding season.

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